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13. ABSTRACT (Maximum 200 words)

Under the support of ARO (Grant number: DAAG55-98-1-0133, Engineering Sciences Division), a three-year basic research program is carried out on the micromechanics of penetrator/target interactions. Emphasis is placed on the basic models for penetrators and targets in the interfacial zone, aiming to provide guidelines for the design of advanced armor/antiarmor systems. The outcomes of this three-year program include (1) A better understanding of the fundamental relationship between the high strain rate deformations and the design parameters in advanced penetrator/armor systems. (2) Micromechanical models that can be used to predict the dynamic behavior of the penetrator and armor interactions. These results have significant implications to the development of new armor/antiarmor systems for the US Army.

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Penetrator/Target Interactions: An Interfacial Layer Approach

FINAL PROGRESS REPORT

GRANT NUMBER: DAAG55-98-1-0133

SUBMITTED TO

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BY

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April 24, 2001

Penetrator/Target Interactions: An Interfacial Layer Approach

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1.0 Project Summary

Under the support of ARO (Grant number: DAAG55-98-1-0133, Engineering Sciences Division, Program Director, Dr. M. A. Zikry), a three-year basic research program is carried out on the micromechanics of penetrator/target interactions. Emphasis is placed on the basic models for penetrators and targets in the interfacial zone, aiming to provide guidelines for the design of advanced armor/antiarmor systems. The outcomes of this three-year program include:

- A better understanding of the fundamental relationship between the high strain rate deformations and the design parameters in advanced penetrator/armor systems.
- Micromechanical models that can be used to predict the dynamic behavior of the penetrator and armor interactions.

2.0 Summary of the Most Important Results

Under impact loading conditions, both penetrator and target materials undergo large plastic deformation with ultra-high strain-rate. This process is very complex - the heat generated due to plastic work causes thermal softening, leading to a dramatic change in material response to the high pressure, high shear rate loading. It is critical to establish the relationships between the thermomechanical properties of the materials involved, and the evolving geometry of the penetrator and target. Specifically, this involves determining the shape of the penetrator "head" at its interface with the target. To establish such a fundamental relationship for optimizing the ballistic performance of penetrator/target systems, under the ARO grant, theoretical research has been conducted to identify the controlling mechanisms responsible for the "self-sharpening" in depleted uranium (DU) and the formation of "mushroomed head" in tungsten heavy alloy (WHA) penetrators, and to develop a predictive model for the evolution of the shape of penetrator head as determined by the striking velocity, the thermomechanical properties of the penetrator and target materials, and the penetrator/target interactions. To analyze such interactions, a boundary layer approach is taken based on the observation that large plastic deformation, frictional sliding, thermal softening and melting are concentrated near the penetrator/target interface. The penetrator/target system is divided into three zones: the interfacial zone, the penetrator body and the target body. Outside the interfacial zone, both the penetrator and target materials are taken as isotropic elastic-plastic, with simple constitutive behaviors such as adiabatic perfect plastic or pure power-law strain and strain rate hardening. The material in the interfacial zone is taken as a mixture of the penetrator and target materials, with the relative volume fractions changing with position. The size and shape of the penetrator head is characterized by a simple mathematical function containing three parameters. The target is assumed to be infinitely large in the radial direction. To predict quantitatively the evolution of the penetrator head geometry during penetration process, boundary value problems for the penetrator body, the interfacial zone and the target body are solved approximately with given functional forms of the temperature, pressure and shear distributions at the interface and other boundaries. The fundamental understanding gained of how the geometry of the penetrator head evolves during penetration may enable one to optimize the ballistic performance by selecting the penetrator or target materials. The predictive models developed in this study can thus have a significant impact on the development of penetrator and target materials, and penetration mechanics.

3.0 List of Publications

1. Bao, G., Rapacki, E. Jr., and Bilyk, S., "A boundary-layer approach for analyzing penetrator/target interactions," Proceedings of 14th Army Symposium on Solid Mechanics (eds. K. Iyer and S. C. Chou), pp. 197-205 (1997).

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2. P. R. LcDuc and **G. Bao**, “Thermal softening of a particle-modified tungsten-based composite under adiabatic compression”, *Int. J. Solids Structures* **34**, 1563-1581 (1997).

3. P. LeDuc, C. Haber, **G. Bao** and D. Wirtz, "Dynamics of Individual Flexible Polymers in a Shear Flow", *Nature* **399**, 564-566 (1999).

4.0 List of All Participating Scientific Personnel

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